Available online at www.sciencedirect.com
ScienceDirect
Int. J. Human-Computer Studies 69 (2011) 551–562
International Journal of Human-Computer Studies
www.elsevier.com/locate/ijhcs

Design and evaluation of freehand menu selection interfaces using tilt and pinch gestures

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Received 16 September 2010; received in revised form 29 April 2011; accepted 16 May 2011
Communicated by S. Boedker
Available online 26 May 2011

Abstract

Freehand gestural interaction, in which the user's hands move in mid-air to provide input, has been of interest to researchers, but freehand menu selection interfaces have been under-investigated so far. Freehand menu selection is inherently difficult, especially with increasing menu breadth (i.e., the number of items), largely because moving hands in free space cannot achieve precision as high as physical input devices such as mouse and stylus. We have designed a novel menu selection interface called the rapMenu (Ni et al., 2008), which is controlled by wrist tilt and multiple pinch gestures, and takes advantage of the multiple discrete gesture inputs to reduce the required precision of the user hand movements.

In this article, we first review the visual design and behavior of the rapMenu technique, as well as related design issues and its potential advantages. In the second part, we present two studies of the rapMenu in order to further investigate the strengths and limitations of the design principle. In the first study, we compared the rapMenu to the extensively studied tilt menu technique (Rahman et al., 2009). Our results revealed that the rapMenu outperforms the tilt menu as menu breadth increases. In the second study, we investigated how the rapMenu affords the opportunity of eyes-free selection and users' transition from novice to expert. We found that within 10 min of practice, eyes-free selection with rapMenu has competitive speed and accuracy with the visual rapMenu and the tilt menu. Finally, we discuss design variations that use other axes of wrist movement and adopt alternative auditory feedback.

Keywords: Menu; Freehand gesture input; Wrist tilt; Pinch; Eyes-free menu selection

1. Introduction

Freehand gestures (i.e., bare hand interactions in free space or mid-air, rather than on a surface) have been expected to deliver "casual" and natural yet powerful interaction, especially in non-desktop scenarios where mice and keyboards are not appropriate or available (Baudel and Beaudouin-Lafon, 1993; Wilson and Oliver, 2003). Researchers have explored a number of application scenarios that can benefit from freehand interaction techniques, such as traditional desktop interactions (Wilson and Oliver, 2003; Wilson, 2006), home entertainment (Lenman et al., 2002; Microsoft, 2010), virtual and augmented reality (Benko et al., 2005; Bowman and Wingrave, 2001; Bowman et al., 2002), and emerging public ambient displays (Vogel, 2004), large high-resolution displays (Vogel and Balakrishnan, 2005), and curved surfaces (Benko, 2009).

Previous research offers freehand gesture techniques for distant pointing and clicking (Vogel and Balakrishnan, 2005), window management (Wilson, 2006), or ad-hoc, application-specific object control (Baudel and Beaudouin-Lafon, 1993). However, research on menu selection interfaces using freehand gestures is rare.

At first glance, it appears straightforward to adopt existing menu systems like direct pointing-based menus (e.g., Nintendo Wii™ menus), marking menus (Kurtenbach, 1993), or the FlowMenu (Guimbretière and Winograd, 2002) to freehand gestures. Most existing techniques, however, were developed

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doi:10.1016/j.ijhcs.2011.05.001

for very different user interface devices that accept direct (e.g., stylus) or indirect (e.g., mouse) pointing input on a surface. When ported to freehand gesture input, these designs may no longer be effective or feasible, largely because moving hands in free space cannot achieve precision as high as physical input devices such as mouse and stylus. Direct pointing, for example, suffers from hand jitter, and even with an advanced low-pass filter, it is difficult to select small targets from a distance (Vogel and Balakrishnan, 2005). Thus, menus have to be made large, taking up much screen real estate (e.g., Wii™ menus) and limiting the number of commands available on the display. Gesture-based menus such as the marking menu (Kurtenbach, 1993) use directional gestures rather than pointing to select items, but they may also be more ambiguous and error-prone to perform with freehand input in mid-air. This is due to the lack of haptic constraints (Wang and Mackenzie, 2000) and distinctive gesture delimiters. In addition, increasing menu breadth requires more directions, making marks more difficult to perform.

In our prior work, we designed a novel menu selection interface called the "roll-and-pinch menu", or rapMenu (Ni et al., 2008), which is controlled by wrist tilt and multiple pinch gestures. It maps tilt and *multiple* pinch gestures to a radial menu layout at two levels of granularity: the user tilts her hands to alter the wrist orientation, which *indicates* a group of menu items that are selectable; then she touches her thumb to one of the other four fingers (forming a pinch gesture) to *commit* a specific selection in that group. The essential design principle behind the rapMenu is to take advantage of the multiple discrete inputs (i.e., the pinch gestures) to reduce the required precision of the continuous and coarse hand gestures (i.e., the wrist tilt). In particular, by leveraging multiple discrete input events generated by pinch gestures, only a rough, imprecise wrist tilt is required to *indicate* a group of menu items. Meanwhile, the tradeoff is that *committing* a selection is slightly more complicated, since it requires the user to decide which pinch to issue.

In designing and informally evaluating the rapMenu, we believe that this design principle was critical and deserved further investigation. In this article, therefore, we analyze in depth this principle and its implications to other aspects of the rapMenu. To do so, we first compared the rapMenu to the extensively studied tilt menu technique, which largely relies on precise wrist tilt to indicate and commit a selection (Rahman et al., 2009). Our results revealed that the rapMenu outperforms the tilt menu as menu breadth increases, which demonstrates the benefits of using gestures that produce multiple discrete inputs along with a rapid and coarse hand-movement gesture. We then present a second study that investigated whether the design principle behind the rapMenu allows for the novice-to-expert transition and eyes-free menu selection, because of the physical mnemonics afforded by the combined use of pinch and tilt gestures. We found that within 10 min of practice, eyes-free selection with the rapMenu has competitive speed and accuracy with the visual counterparts.

In the following sections, we review previous literature, provide an extended description of the rapMenu technique, design principle, and its potential benefits, and present the two user studies in greater details. We conclude with a discussion of extending the rapMenu design to use other axes of wrist movement and adopt alternative auditory feedback to potentially improve the eyes-free selection.

2. Related work

The work in this article builds on previous research on menu techniques and gesture input.

2.1. Menus using gestures

The marking menu (Kurtenbach, 1993) is a well-known gesture-based menu technique, which allows the user to perform a selection either by popping up a menu or drawing a mark in the direction of the desired item. It therefore encourages the user to learn directional gestures, and allows the expert user to operate in an eyes-free manner. Similar techniques such as the control menus (Pook et al., 2000) and the FlowMenu (Guimbretière and Winograd, 2002) effectively merge command selection and direct manipulation. Such menus were primarily designed for devices that accept pointer input directly or indirectly on a surface.

On the other hand, many 3D menus designed for mid-air operation have been proposed for virtual and augmented reality (Dachselt and Hübner, 2007). In particular, the ring menu (Liang and Green, 1994) is a radial menu that is conceptually the same as the tilt menu techniques (Rahman et al., 2009) and controlled by wrist tilt. The TULIP menu (Bowman and Wingrave, 2001) uses multiple pinch gestures to allow simultaneous access to multiple menu items assigned to particular fingers, but forces the user to use a specific pinch to "scroll" through longer menus.

2.2. Tilt interaction

Tilt techniques are becoming ubiquitous today as accelerometers are integrated with many mobile devices. Researchers have demonstrated a number of designs that explore tilt input beyond simple image rotation or content scrolling. In particular, it is common to break up the raw angular space available with wrist tilt and group nearby values into unique controllable tilt levels (Rahman et al., 2009).

Oakley and O'Modhrain (2005) described the use of handheld device orientation to directly control list position, rather than the rate of list traversal. Each menu item was selected by tilting the device at an angular position. They also demonstrated that this position-based mapping resulted in lower error rate than a rate-based mapping. TiltText (Wigdor and Balakrishnan, 2003) and TiltType (Partridge et al., 2002) enable faster text entry on cell phones by pressing a button and tilting the device in a